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Cost Optimization of Batik Production Process Using Artificial Immune System Algorithm

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Abstract. This paper proposes the batik production process optimization based on Artificial Immune System (AIS) algorithm. AIS algorithm is computational paradigms that belong to the computational intelligence family and are inspired by the biological immune system. In this research, AIS algorithm is used to optimize the material of production process of batik which consists of cloth, dye, wax, water, oil fuel, and electric energy. At all stages of the process, the main objective of the optimization is to minimize production costs and processing time. Application of AIS algorithm has been applied to the batik industry in Yogyakarta, Indonesia. The results showed that the AIS algorithm is able to provide optimal results in determining the use of materials. At the same time, the optimization also generates optimal production time. Optimization results show that there is a saving of raw materials of 10.2482% and production process time savings of 10.7438%. These savings would have an impact on improving operational efficiency in the batik industry. This optimization is expected to help strengthen of the competitiveness of Yogyakarta batik industry.

Keywords— Artificial immune system algorithm; batik; production process; optimization.

INRODUCTION

Artificial immune system (AIS) algorithm is one of the most popular in optimization algorithm. The advantage of AIS algorithm is relatively low computational load to achieve convergence and accuracy of the results was good. Many researchers have felt the advantages of this algorithm, some of which will be described here.

Artificial immune systems are computational paradigms that belong to the computational intelligence family and are inspired by the biological immune system [1]. During the past decade, they have attracted a lot of interest from researchers aiming to develop immune-based models and techniques to solve complex computational or engineering problems. Similarly to other bio-inspired computing paradigms, the AIS intend to capture some of the immune system principles and processes previously described within a computational perspective. The main objective is to utilize the appealing features of the natural immune system including pattern recognition, learning, memory and self-organization.Alternatively, the artificial immune network approaches were used in clustering, classification, data analysis and data mining applications. The clonal selection models were used mostly for optimization problems [1]-[2].

ARTIFICIAL IMMUNE SYSTEM

The general AIS algorithm that used in this research consists of the following steps:

1. Initialization: Set a random population of individuals p

2. Affinity evaluation: Measure the affinity of each individual in the population that generate in step 1

3. Selection: Selection on the population and find the n best individuals of the population based on the affinity measure.

4. Expansion: Clone the n best individuals of the population proportional to the rate of cloning. The clone is an identical copy of the original string. (The clone size is an increasing function of the affinity measure.)

5. Affinity maturation: Mutation on each clone to generate a matured antibody of the population. Preserve the improved individuals for the next generation.

6. Metadynamics: Replace R individuals with low affinity value with randomly generated new ones. The lower affinity cells have higher probabilities of being replaced. This process introduces diversity into the population.

7. Cycle: Repeat step 2-6 until a certain stopping criteria is met.

The analogy with natural selection fit the reality that is the strongest candidate into most cells recognizes antigens. In order to explain this algorithm, population or repertoire of receptors should be diverse enough to recognize any form of foreign cells. A mammalian immune system contains a heterogeneous repertoire of about 10^{12} lymphocytes in humans, and the rest of B cells can display about 10^5-10^7 identical like-antibody receptor. Repertoire has been believed complete means that he can recognize the shape of any cell.

The algorithm of ClonalG is based on clonal selection theory. The method is used to explain the basic response of adaptive immune system to antigenic stimulus. It establishes the idea that only those cells capable of recognizing an antigen will proliferate while other cells are ignored. Clonal selection operates on both B and T cells. B cell are activated and differentiated into plasma or memory cells. Clones of B cells are produced and undergo somatic hyper mutation. As a result, diversity is introduced into the B cell population. Plasma cells produce antigen-specific antibodies that work against antigens. Memory cells remain with the host and promote a rapid secondary response.

The steps of clonal selection of AIS are described in the following algorithm.

```
Input: Ab, gen, n, d, L, β;
// Ab: available antibody repertoire
// gen: no of generations
// n: no of antibodies to select for cloning
// d: lowest affinity antibodies to be replaced
// L: bit string length for each antibody
// β: cloning factor
Output: Ab, f
    for t = 1 to gen,
    f := decode (Ab); vector f contains all affinity antibodies that bind to the antigen
    Abn := select (Ab, f, n);
    C := clone (Abn, β, f);
    C* := hypermut (C, f);
    f := decode (C*);
    Abn := select (C*, f, n);
    Ab := insert (Ab, Abn);
    Abd := generate ( d, L ); randomly generate antibody d along L
    Ab := replace (Ab, Abd, f);
    end;
    f := decode (Ab); Decode functions are supposed to encode Ab and evaluation for values decode.
```

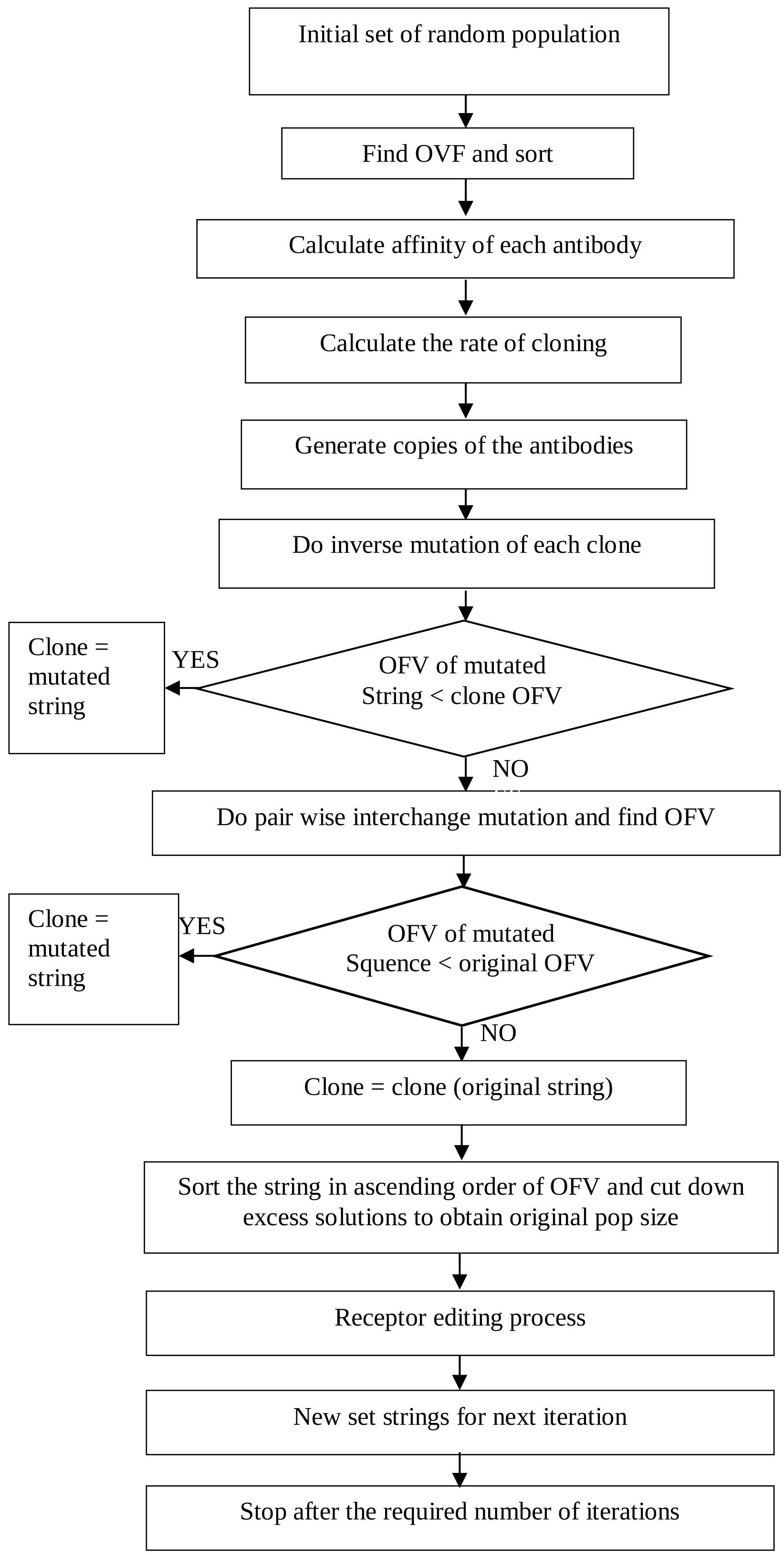

FIGURE 2. Flowchart of artificial immune system

For affinity maturation, ClonalG algorithm assumes that the n highest affinity antibody is sorted rise, and the number of clones that are raised for all n selected antibodies are given by:

$$Nc = \sum_{i=1}^{n} round\left(\frac{\beta \cdot N}{i}\right) \tag{1}$$

with N is the total number of clones for each antigen, β are the cloned factor determining the scale factor for the number of clones for antibodies elected and β common value is $\in (0,1]$, N is the total amount of antibodies and round() is operators who rotate argument to the nearest integer. Each part of this amount corresponds to the size of clones of each antibody chosen, for example, for N = 100 and β = 1, antibodies highest affinity (i = 1) will produce 100 clones, while the antibody affinity the second highest yield of 50 clones, and thus further.

The flowchart of artificial immune system algorithm is shown in Fig. 2.

BATIK PRODUCTION PROCESS

The batik tradition is particularly prevalent on the Java island and was handed down from generation to generation. Batik is created either by drawing dots and lines of the resist with a spouted tool called a *canthing*. The process of making batik is described as follows [5].

1. Designing process

   The first process is a process of drawing or sketching that wanted in the mori, cotton, or silk using a pencil or pen, as shown in Fig. 3.

FIGURE 3. Process of designing

2. *Pencantingan* process

   After designing, the second step is *pencantingan*. This is a painting fabric with wax using the canting by following a pattern that has been made on both sides of the fabric, as shown in Fig. 4.

FIGURE 4. *Pencantingan* process

3. Process of Staining

   The process is the coloring process by chemical or natural color, on the part that is not covered by wax by dipping the cloth in a particular color. Once dry, re-do the batik process that is painted using wax using canting using canting to cover parts that will be maintained in the first coloring.

4. Process of *Pelorodan*
   The next process is to remove the wax of the fabric by putting or boiling the cloth in hot water.
5. Process of Opening and Closing of Patterns
   The process of opening and closing the wax can be repeated according to the number of colors and the complexity of the desired motif.
6. Process of Washing and Drying
   The next process is to wash the batik cloth and then dry it by way of drying or cooling it down in the shade.

BATIK PROCESS OPTIMIZATION

The objective of optimization in this research is to minimize production costs include raw materials and processing time in the production process of batik in order to obtain maximum benefit [5]. The objective functions in the optimization are shown in the following equations:

a. Minimization of materials

$$f_1(X) = \sum_{i=1}^{k} R_i \tag{2}$$

b. Minimization of processing time

$$f_2(X) = \sum_{i=1}^{k} T_i \tag{3}$$

The multi-objective formulation of batik production process could be defined as follow:

$$\begin{aligned} \max J(X) &= \| f(X) - f_0 \|_2 \\ &= \sqrt{\left(f_1(X) - f_{o1}\right)^2 + \left(f_2(X) - f_{o2}\right)^2} \end{aligned} \tag{4}$$

Subject to:

$$F(x) = 0 \tag{5}$$

$$T_{i,\min} \le T_i \le T_{i,\max} \tag{6}$$

$$R_{i,\min} \le R_i \le R_{i,\max} \tag{7}$$

where f_1(X) is a cost function of raw materials; f_2(X) is a cost function of processing time; R_i is a raw variable of batik and T_i is a processing time variable of batik processing [5].

Furthermore, based on cost functions as expressed in the equation (2) to the equation (5) conducted a multi-objective optimization to optimize the production process of batik in one of Yogyakarta batik industry.

RESULTS AND DISCUSSION

This section describes the results and analysis of multi-objective optimization of the production process of batik using artificial immune system (AIS) algorithm. The objective functions are the optimization of raw materials and the processing time to produce 100 pieces of batik cloth, as shown in Table I. In Table I are shown the materials used in each production process of batik. In the process of design and drawing to the cloth, the main material that is required is a piece of white fabric, while the supporting material is cotton, *mori*, silk and atbm (handmade).

Subsequently in the process *pencantingan* and *nembok* then the required material are such as wax and oil fuel. In the process of staining, the main raw material is a dye which is made up of chemicals and natural ingredients (i.e. indigo, pace or mulberry tree). In the process of *pelorodan*, the main raw material is hot water. To produce hot water needed raw water and fuel oil. Water is also needed in the washing process. After being washed, the next process is drying batik cloth. In this process takes a dryer that is a fan and electrical energy. The last process is the finishing and packaging. In this process the required material is paper and plastics. Overall the raw materials needed optimized to obtain savings in the production process of batik.

TABLE I
MATERIALS IN BATIK PROCESS PRODUCTION

No	Materials		Stage of Process
1	A piece of white fabric	Cotton	Design and Drawing to the cloth
		Mori	
		Silk	
		Atbm (handmade)	
2	wax	wax	Pencantingan, nembok
		Oil fuel	
3	dye	chemical	Staining
		Natural (indigo, pace or mulberry tree)	
4	hot water	Water	Pelorodan
		Oil Fuel	
5	water		Washing
6	Dryer	Fan	Drying
		Electric Power	
7	Paper, plastics		Finishing and Packaging

CONCLUSION

Optimization of the production process of batik using AIS algorithm in research has yielded significant results. Optimization results show that in batik production process, there is a saving of raw materials amounted to 10.2482%, where the material cost before optimization is US$ 850.10 and after optimization is US$ 759.20. The successful is also showed at the optimization of production time savings of 10.7438%, where of the process time before optimization is 121 hours and after optimization is 108 hours. These savings would have an impact on improving operational efficiency in the batik industry. This optimization is expected to help strengthen of the competitiveness of Yogyakarta batik industry.

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